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ABSTRACT

Reported is a study to assess the Piagetian level of performance of males and females on two manipulative tasks of concrete and formal reasoning abilities and a written examination of concrete and formal reasoning abilities. Sixty-two high school students, 31 males and 31 females, were randomly selected from a biology course at Delphi High School in Delphi, Indiana. The data suggest that the format of the testing situation differentially affects males' and females' ability to demonstrate concrete and formal reasoning abilities. Males performed significantly better than females on the manipulative reasoning tasks, that is, at a somewhat more formal level than the females in this study. (Author/DS)

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SEX DIFFERENCES IN CONCRETE AND FORMAL
REASONING ABILITY AS MEASURED
BY MANIPULATIVE TASKS AND
WRITTEN TASKS

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SEX DIFFERENCES IN CONCRETE AND FORMAL REASONING ABILITY AS MEASURED BY MANIPULATIVE TASKS AND WRITTEN TASKS

Fogelman (1969) reported that, on Piaget's test of conservation of quantity, first grade boys demonstrated significantly more conservation responses when they actively manipulated the conservation materials than when the examiner performed the necessary manipulations himself. However, girls showed the opposite result. For them significantly more conservation responses were demonstrated when the examiner performed the manipulations than when they actively manipulated the materials. Over all, the girls' performance was slightly superior to that of the boys. These results show that males' and females' ability to demonstrate conservation reasoning may differ with respect to the format of the testing situation. This finding suggests the possibility that males and females may also differ in their ability to demonstrate formal reasoning depending upon the format of the testing situation (i.e., whether the tasks involve manipulations of materials or pencil and paper responses).

The purpose of this investigation was to assess the Piagetian level of performance of males and females on two manipulative tasks of concrete and formal reasoning abilities and a pencil and paper examination of concrete and formal reasoning abilities. The study addressed itself to the following questions:

1. Do males perform at a significantly higher (more formal) level than females on manipulative tasks of concrete and formal reasoning?
2. Do females perform at a significantly higher (more formal) level than males on a written examination of concrete and formal reasoning?
3. Overall, do males and females demonstrate significant differences in their ability to reason formally?
4. Do the manipulative tasks and pencil and paper examinations seem to be measuring different psychological parameters depending upon the sex of the examinee?

If significant sex differences are found in students' ability to reason on examinations of varying format, these differences should be taken into consideration when assessing reasoning abilities. Further, if a comparison of males' and females' performance on manipulative and written measures shows one sex performing at more formal level on both types of examination, then the question of why such a result is obtained is raised.

METHOD

Subjects

Sixty-two high school students (31 males and 31 females) were randomly selected from a required second semester biology course at Delphi High school in Delphi, Indiana. The males ranged in age from 14.4 years to 17.5 years with a mean age of 15.2 years. The females ranged in age from 14.2 years to 17.1 years with a mean age of 15.2 years. Delphi High School is a modern school with over 800 students located in a rural section of North Central Indiana. The principal occupation of the residents is farming.

Instruments

The Manipulative Tasks. Two Piagetian tasks which required manipulations of materials and concrete and formal reasoning for successful completion were administered in individual interviews. The tasks were (1) bending rods (Inhelder & Piaget, 1958, pp. 46-66); (2) equilibrium in the balance (Inhelder & Piaget, 1958, pp. 164-181). Since the tasks and scoring procedures have been described in detail elsewhere (Lawson, Nordland and DeVito, 1975), only brief descriptions will be included here.

Bending rods. This task tested the subject's ability to identify and control variables. Given six flexible metal rods of varying length, diameter, shape, and materials, and hanging weights, the subject was asked to identify variables and demonstrate proof of the affect of each variable on the amount of bending of the rods.

Equilibrium in the balance. Using a balance beam and hanging weights, this task tested the subject's ability to balance various combinations of weights at various locations along the beam, e.g., given a 10 unit weight 7 units of length from the fulcrum, the subject was asked to predict the proper location to suspend a 5 unit weight to achieve a balance. Successful completion of this task implied understanding of inverse proportion.

Piagetian level of performance on the tasks was assessed on the basis of the quality of subjects' verbal responses and their ability to exhibit appropriate behaviors, i.e., to control variables on the bending rods task and to hang weights in correct locations on the equilibrium in the balance task. Task responses were categorized and points awarded as follows:

Early concrete operational - IIA, zero points

Fully concrete operational - IIB, one point

Early formal operational - IIIA, two points

Fully formal operational - IIIB, three points

The Pencil and Paper Examination. A pencil and paper examination developed by Longeot (Longeot, 1962; Longeot, 1965) was chosen as the written examination of concrete and formal reasoning abilities. This examination was administered to groups of subjects by the classroom instructors. The examination consisted of 14 items subdivided into three parts.* Part I consisted of proportionality problems of which two items required only concrete thought and three items required early formal thought (formal IIIA). Part II consisted of six problems called detective stories. Each problem involved propositional logic and required formal thought for successful completion. Part III involved four combinatorial problems, two problems required concrete thought and two problems required formal thought.

*The original Longeot examination consisted of 28 problems subdivided into four parts. One section which included only concrete operational questions plus a few problems from the other sections of the original were omitted to shorten the examination to allow its administration during one class period.

Examples of the items are shown below:

Part I. Proportionality. Early formal - IIIA.

The first garage holds 24 vehicles; there are 4 trucks and 20 cars there now. The second garage holds 54 vehicles; it now has 9 trucks and 45 cars in it. The third garage holds 36 vehicles, with 6 trucks and 30 cars in it now. Unknown to the drivers, each garage has a "Lucky Parking Spot." In which garage is it most likely that a truck is parked in the lucky spot?

Conclusions:

- A. In the third garage for it contains more trucks than the first garage and fewer cars than the second garage.
- B. In the second garage for this one contains the most trucks.
- C. In the first garage for this one contains the fewest cars.
- D. In any of the garages, for they all have the same number of trucks in relation to the total number of their vehicles.

Part II. Propositional logic. Fully formal - IIIB.

If you are going to go swimming then it is nice weather. If you are going boating, then it is nice weather. Finally you are going boating.

Conclusions:

- A. It is nice weather.
- B. It is not nice weather.
- C. You are going swimming.
- D. You are not going swimming.
- E. One cannot know whether you are going swimming.

Part II. Combinatorial Analysis. Fully formal - IIIB.

How many numbers of two figures are there when the numbers are made with the figures 1, 2, 3, 4, 5? Write the total amount of numbers on the answer sheet. (Do all the figuring in your head.)

Scoring. According to the procedures described by Longeot, subjects were categorized into the Piagetian levels on each part of the examination as follows: Part I, 0-1 items correct placed the subject into level IIA; 2-3 items correct placed the subject into level IIB; 4-5 into level IIIA. Part II, 0 IIB; 1-3 IIIA; 4-6 IIIB*. Part III, 0 IIA; 1-2 IIB; 3 IIIA; 4 IIIB. Points were awarded for each level as above.

*Since the Longeot examination uses a multiple choice format, some correct responses could be obtained by chance alone. Because of the scoring procedures used in Part II these correct responses would be reflected in increased levels of thinking ability. This error was avoided by adjusting the scores as follows: Subjects who got no items correct were classified as concrete-IIB thinkers. Subjects who got one of the 6 items correct were classified as formal-IIA thinkers. However, since the probability of getting each problem correct by chance was .1 and since there were 6 problems, the probability of scoring one of 6 correct by chance alone and being misclassified at level formal-IIIA was $6(.1 \times .9^5) = .35$. For this reason, .35 of the subjects who scored one item correct were reclassified into the concrete-IIB level.

Additional Measures. In addition to the two manipulative tasks and the pencil and paper examination, a conservation of weight task and a volume displacement task were administered to each subject in individual interviews. In both tasks the subject handled the materials; however, in the conservation of weight task the transformation of the clay ball was carried out by the examiner.

The conservation of weight. (e.g., Elkind, 1961) Two balls of clay of approximately 50 grams each were presented to the subject. If he did not accept that the balls weighed the same he was asked to adjust them until he believed that they did. The examiner then flattened one of the balls of clay into a "pancake" shape and asked the subject: Do the two balls of clay weigh the same? Does the "pancake" shaped piece weigh more? Or does the ball weigh more? Why? Responses were scored as correct if the subject answered that the pieces still weighed the same and justified his belief with one of the following arguments. (a) You did not add or subtract any clay. (b) They weighed the same before so they still weigh the same. (c) The "pancake" is flatter but it is also wider so it still weighs the same.

Volume displacement. (Karplus and Lavatelli, 1969) Two metal cylinders of equal volume but different weight (18-g and 55-g) were handed to the subject. The equal height and thickness of the metal cylinders was pointed out. The examiner then took the cylinders and lowered the lighter one into one of the two test tubes (30 ml) which were partially filled with equal amounts of water. The rise in water level was noted and the subject was asked: When the heavier cylinder is placed into the second test tube will the water level rise higher? Will the water level rise lower? Will the water level rise the same as in the first test tube? Why? Responses were scored correct if the subject said that the water levels would rise the same and justified his belief by saying that it was because the metal cylinders were: (a) the same size, (b) the same height, (c) the same height and thickness, (d) took up the same space, or (e) were equal in volume. Questions for both the conservation of weight task and the volume displacement task were asked in a counterbalanced order.

RESULTS

Table 1 shows the mean Piagetian levels for both males and females for the manipulative tasks and the three sections of the Longeot pencil and paper examination. To test whether the differences between the males and females were significant the Mann-Whitney U test was used (Siegal, 1956; pp. 116-127). The obtained U values are shown in the table as are the related z values. The z values reflect converted U values after taking tied ranks into consideration. For all the measures the males' mean level was higher than that of the females. The differences reach significance ($p < .02$) for the manipulative tasks, however, only the propositional logic section of the Longeot pencil and paper examination showed a substantial difference in favor of the males ($z = 1.36, p < .10$).

Table 1

MEAN PIAGETIAN LEVELS AND STANDARD DEVIATIONS OF MALES AND
FEMALES FOR THE PIAGETIAN TASKS AND LONGEOT EXAMINATION

Measure	Males		Females		U	Z
	Mean	S.D.	Mean	S.D.		
<u>Manipulative Tasks</u>						
Bending Rods	1.80	.49	1.39	.62	304	**2.32
Balance Beam	1.87	.57	1.39	.62	293	**2.71
<u>Written Tasks</u>						
Proportions	1.47	.40	1.35	.46	440	.78
Propositional Logic	1.74	.45	1.54	.49	387	*1.36
Combinatorials	2.33	.52	2.23	.42	419	.46

*p<.10, **p<.02.

The number of conservation and nonconservation responses demonstrated by males and females on the conservation of weight and volume displacement tasks are shown in Table 2. For both tasks the males demonstrated more conservation responses than the females. The difference in number of conservation of weight responses was not significant ($X^2 = 3.25$, $df = 3$, N.S.). However, the difference in the number of conservation responses for the volume displacement task was highly significant ($X^2 = 15.08$, $d.f. = 3$, $p<.001$).

TABLE 2

CONSERVATION (+) AND NONCONSERVATION (-) OF WEIGHT AND
VOLUME DISPLACEMENT FOR MALES AND FEMALES

Task	Males		Females		Chi ²
	+	-	+	-	
Weight	29	2	24	7	3.25
Volume Displacement	20	11	5	26	*15.08

*p<.001

To assess whether or not the two manipulative tasks and the pencil and paper measures were measuring different psychological parameters for the group as a whole and for the males and females taken separately, three principal components analyses of the data were conducted. The analyses were conducted using program FACTOR, a standard program which is contained in the Statistical Package for the Social Sciences (Nic, Bent and Hull, 1970). The program extracts only components with eigenvalues greater than one (Kaiser, 1960) and uses the varimax method of axes rotation. The results of these analyses appear in Table 3. Column 1 of Table 3 shows the factor loadings for each measure for the scores of the males and females combined. Only one factor was extracted which accounted for 48.7% of the total variance of the scores. All five measures loaded substantially on this factor (0.62 to 0.74). Column 2 shows the factor loadings for the scores of the males alone. As was the case for combined sexes, only one factor was extracted. This factor accounted for 49.9% of the total variance. Similar high loadings for each measure were found (0.66 to 0.78). The analysis of the female scores shown in columns 3 and 4, however, revealed two factors. These factors accounted for 48.2% (factor I) and 20.5% (factor II) of the total variance. Interestingly the pencil and paper measures loaded substantially on the first factor (0.59 to 0.92) while the manipulative tasks loaded substantially on the second factor (0.77 and 0.86).

TABLE 3
PRINCIPAL COMPONENTS ANALYSIS

Measure	Factor Loadings*			
	Males and Females	Males	Females	
	Factor I	Factor I	Factor I	Factor II
<u>Manipulative Tasks</u>				
Bending Rods	.62	.68	.02	.86
Balance Beam	.74	.78	.30	.77
<u>Written Tasks</u>				
Proportions	.74	.74	.92	.05
Propositional Logic	.69	.66	.80	.16
Combinatorials	.69	.67	.59	.40

*After varimax rotation.

DISCUSSION

These data suggest that the format of the testing situation differentially affects males' and females' ability to demonstrate concrete and formal reasoning abilities. Males performed significantly better than females on the manipulative reasoning tasks. This result is similar to that obtained by Fogelman mentioned previously. Work by Tyler (1965) also suggests that females are usually less apt than males in solving problems that require active restructuring of stimulus elements. Although the differences between the males and females on the Longeot pencil and paper examination were less than that for the manipulative tasks, the males did demonstrate higher (more formal) scores on all three sections. Male and female differences were further demonstrated by the significantly greater number of conservation responses exhibited by the males on the volume displacement task. Overall it appears that the type of reasoning assessed by these measures may be more highly developed in the males than in the females of this sample.

The results of the principal components analysis provides further evidence to support the hypothesis that the format of the task differentially affects males and females. Since only one factor was extracted when the scores of the males were analyzed, it suggests that only one psychological parameter was being measured by the manipulative tasks and the pencil and paper measures for the males. However, analysis of the scores of the females revealed two separate factors with the manipulative tasks loading on one factor and the pencil and paper measures loading on the other. For the females in this sample then it appears that the manipulative tasks were measuring one parameter while the pencil and paper tasks were measuring a somewhat different parameter. The analysis of the scores of the males and females combined showing only one factor masks this difference.

Since the males did perform at a somewhat more formal level than the females the question of why is raised. Of course the sampling used for this study in no way attempted to provide a sample representative of all adolescent groups. The population examined here could best be described as semi-rural. Sarni (1973) working with a sample of suburban sixth through ninth grade students from the San Francisco Bay area reported no sex differences on Piaget's chemical combinations and specific gravity tasks. Data from Friot's work (Friot, 1970) with eighth and ninth grade students in Norman, Oklahoma, however showed males performing more formally than females on six Piagetian tasks.

Interestingly, not only the format of the testing situation seems to influence results but the sex of the examiner may as well. Most studies of conservation abilities of young children show either males to be superior or no sex differences (e.g., Goldschmid, 1967; Goldschmid and Bentler, 1968; Almy, Chittenden and Miller, 1967; Braine, 1959; Dodwell, 1961; Uzgiris, 1964). Brekke and Williams (1973) however point out that in these studies the examiners were most often males. They showed that in tests of conservation of number and substance first grade females demonstrated significantly more conservation responses ($p < .01$) than first grade males when the examiner was a female. All the testing done in the present study was done by male examiners. In a more recent study of fifth and seventh grade students' ability to utilize conservation reasoning on Piaget's conservation of weight and volume displacement tasks (Lawson and Wollman, in preparation*), male examiners tested the male subjects while female examiners tested the female subjects. In this study, fifth grade females demonstrated proportionally more weight conservation

*Lawson, Anton E., and Wollman, Warren T., "Encouraging the Transition from Concrete to Abstract Cognitive Functioning--An Experiment," in preparation.

responses than fifth grade males but in the seventh grade sample no sex differences were found. On the volume displacement task no sex differences were found in the fifth grade sample, but in the seventh grade group males demonstrated proportionately more conservation responses than females. In other words the males improved relative to the females on both tasks in the older sample.

If it is the case that male adolescents perform more formally than females then the shift in superiority seems to come about roughly towards the end of elementary school years and during the junior high school years.

Interestingly, conservation reasoning ability has been shown to be positively related to the cognitive style of field independence* (Fleck, 1972). Fleck found that in kindergarten, first, and second grade boys, the relatively field independent subjects demonstrated significantly more conservation responses in a battery of conservation tasks than the relatively field dependent subjects ($p < .01$). Also males have been found to be consistently more field independent than females (e.g., Witkin, 1950; Witkin et al., 1954, 1962; Bieri et al., 1968; Gross, 1959). Work by Goodenough (1963) confirmed these findings by a large number of studies in various cultures. However, according to Goodenough and Eagle (1963) these sex differences do not emerge until sometime after the eighth year of age. In light of these findings, then, the apparent male superiority in conservation reasoning which appears towards the end of the elementary school years and in at least some aspects of formal reasoning during adolescence may be due in part to the fact that males are relatively more field independent than females.

Additional research is being initiated to more closely document when and to what extent in the course of development these possible male-female differences in reasoning ability become apparent and to what extent they are related to the cognitive style dimension of field independence--field dependence. Perhaps if we knew when these differences begin, and to what extent they actually exist, we would be in a better position to observe possible variables which may be differentially affecting males and females and consequently be better able to isolate the factors which contribute to the promotion of formal operational thought.

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*Witkin et al., (1962) describe a field independent person as one who is able to overcome an embedded context-to experience an item independently of the organized field of which it is a part and by which it is strongly influenced. Conversely the relatively field dependent person tends to perceive his surroundings in a more global fashion and is much more influenced by the perceptual field. The similarity between the cognitive style dimension of field independence--field dependence and Piaget's description of the non-conserving individual as "perception bound" is very apparent.

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